Advanced Spacecraft Systems Design using Model-based Techniques

Volker Schaus, Daniel Lüdtke, Andreas Gerndt

German Aerospace Center (DLR)

Simulation and Software Technology

Software for Space Systems and Interactive Visualization

Federated Satellite Systems
Workshop 14th Oct 2014

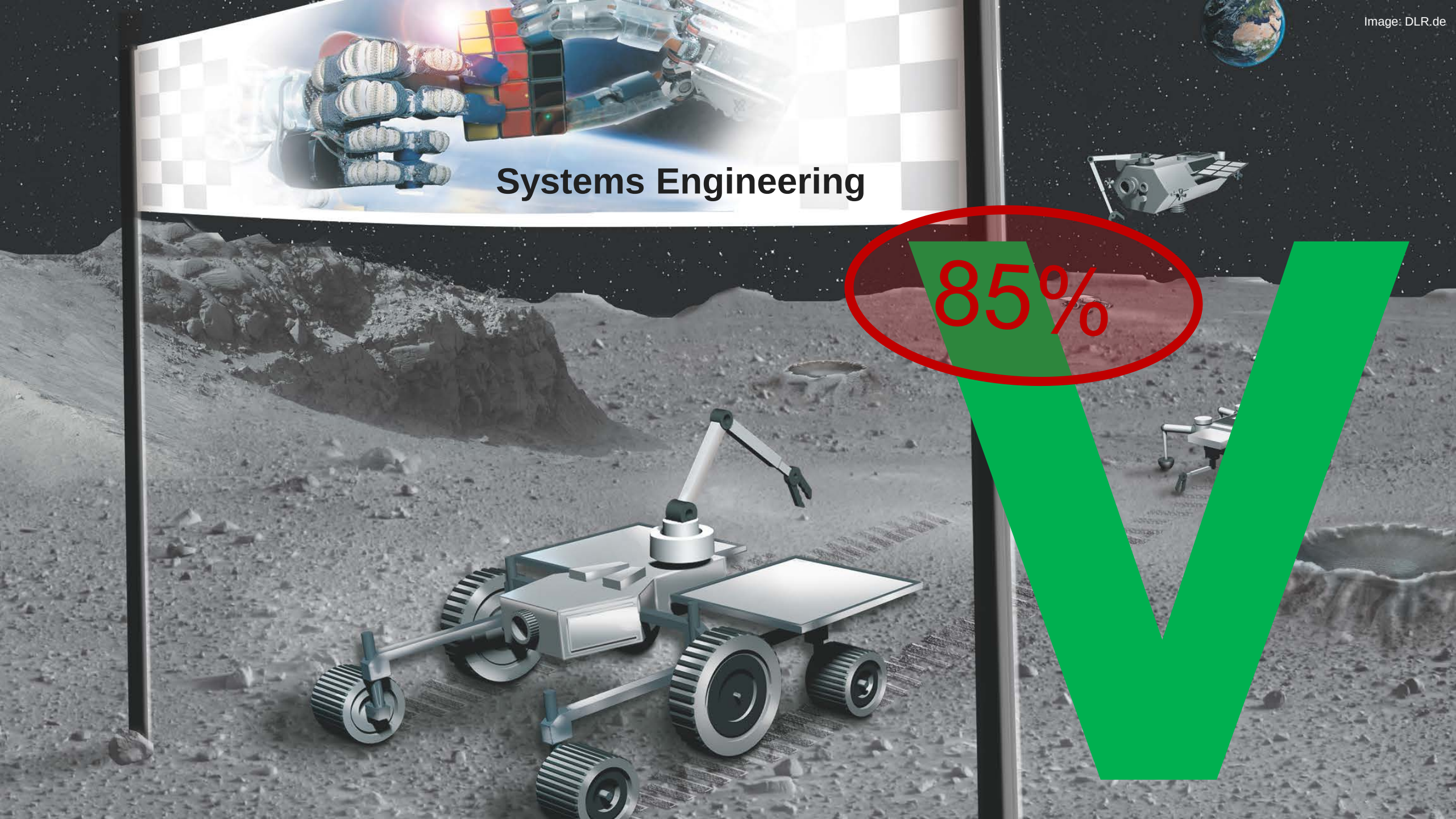
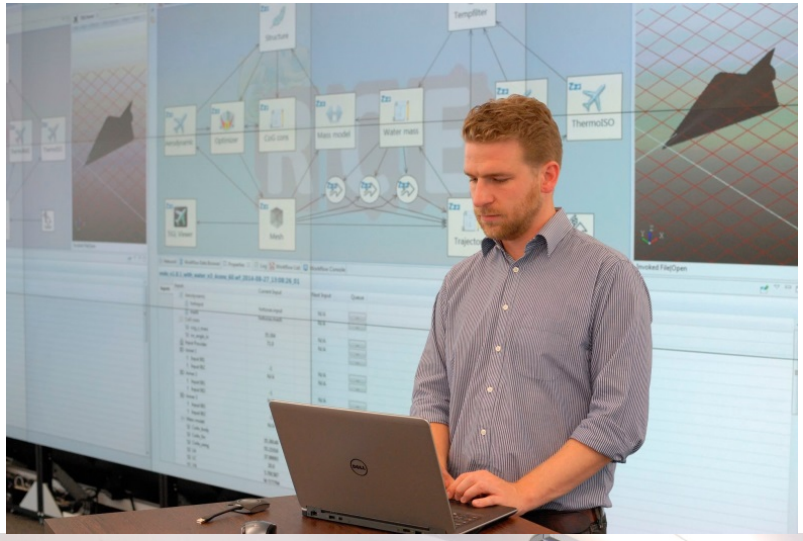


Image: DLR.de

Concurrent Engineering Facility

INTEGRATED **DESIGN** LAB



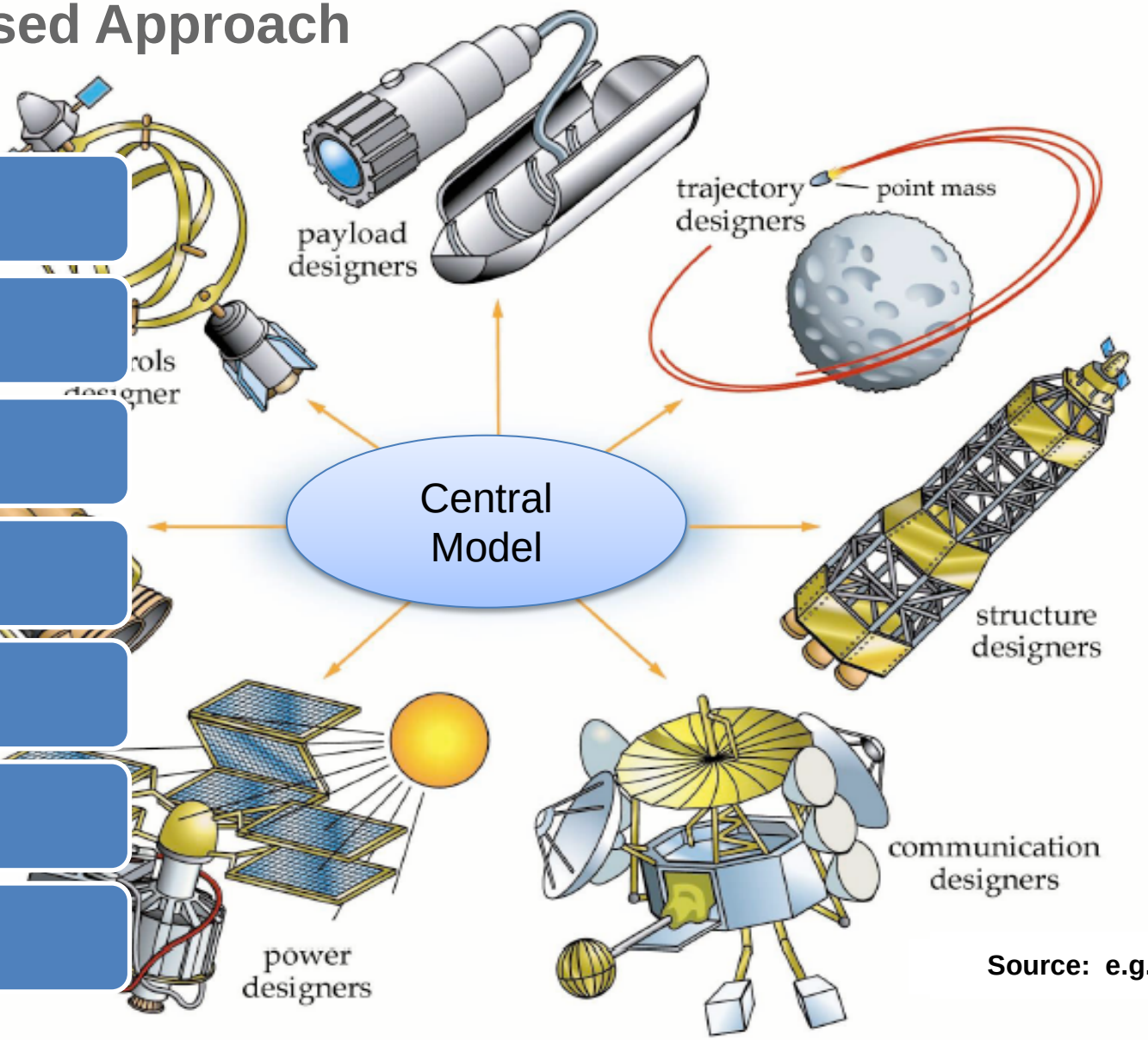
Used for preliminary aircraft design studies, air traffic management and scenario analyses

Flexible arrangement of desks depending on study requirements

Currently: Focus on multi-disciplinary design and optimization

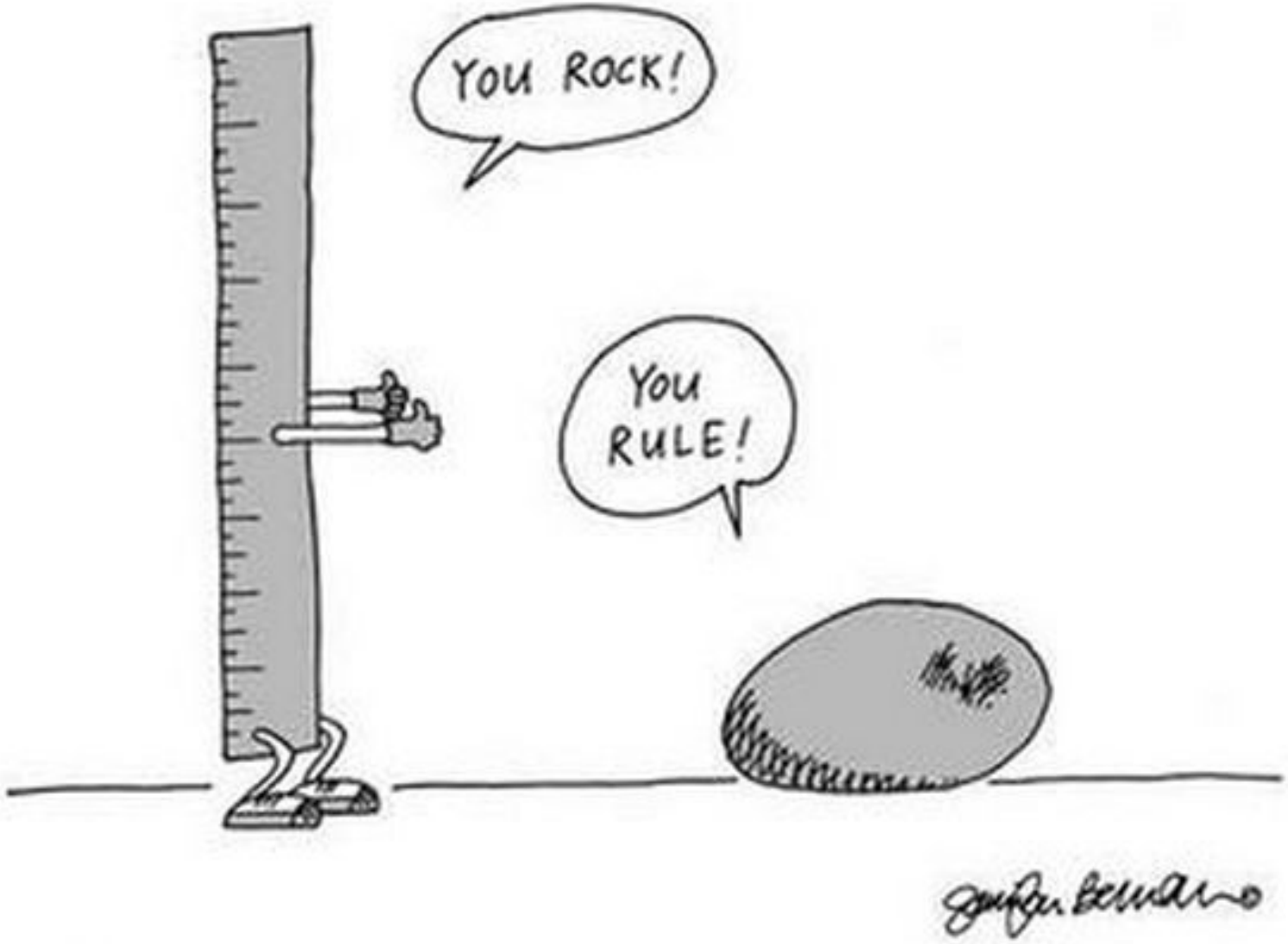
Taking Advantage of the Model-based Approach

- Documents vs Models
- Consistency
- Structure Unstructured Data
- Improve Systems Understanding
- Better Design -> Reduce Cost
- Process Supported by Software
- Tool Development

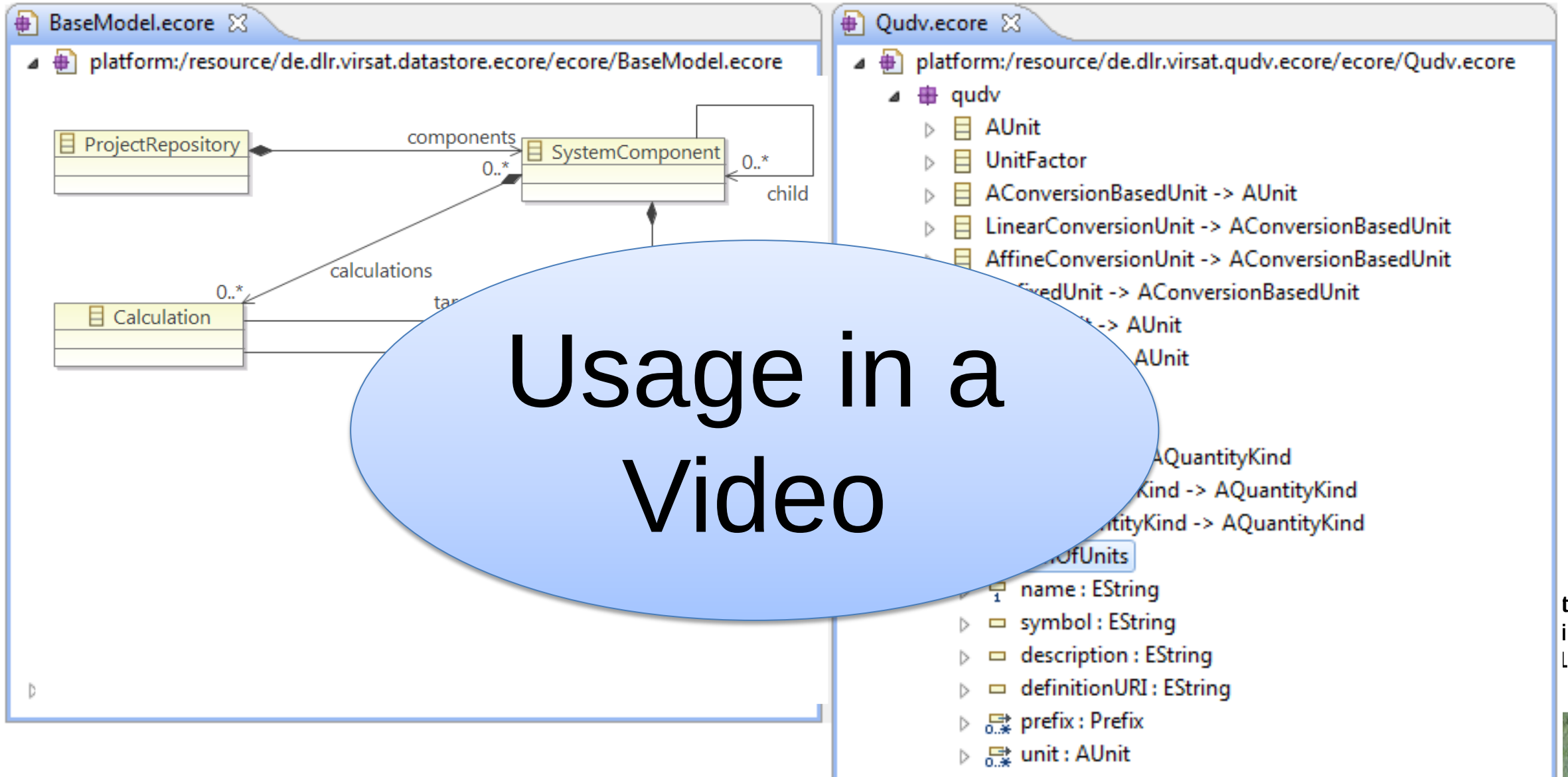


Source: e.g. TSTI

Semantics



Adding Semantics – Unit Management Example



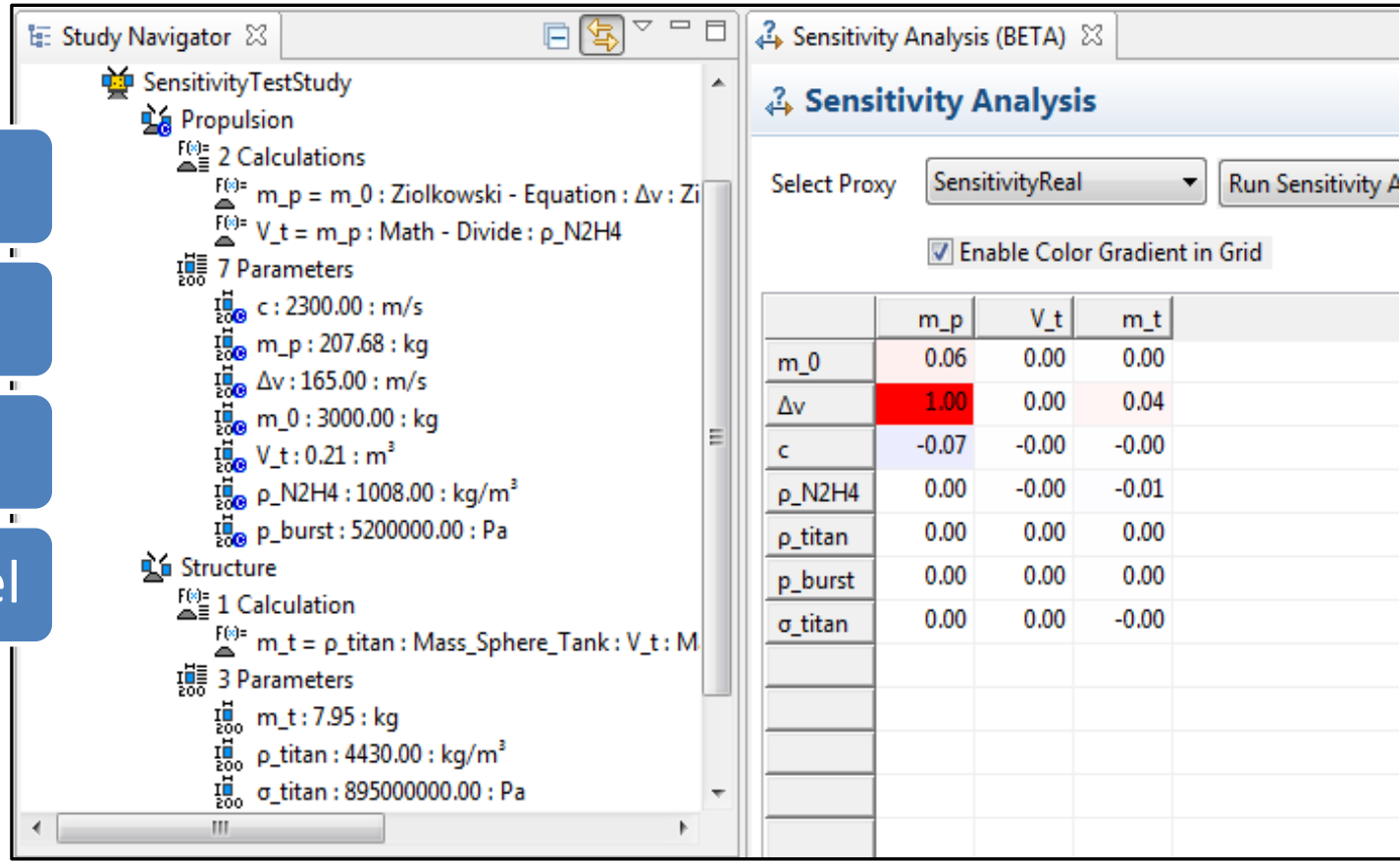
Usage in a Video

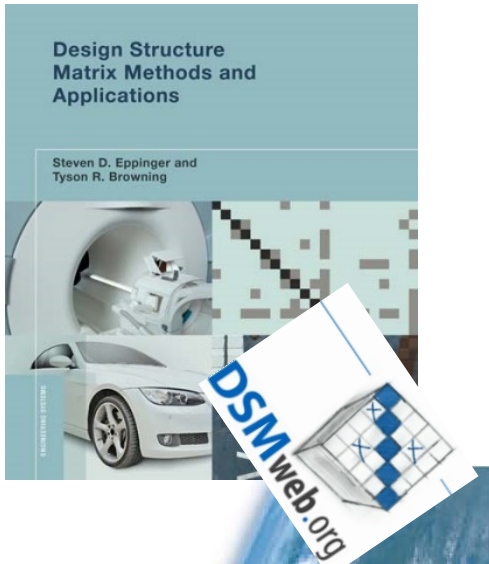
the
in
L3,

System(s) Analyis

Sensitivity Analysis

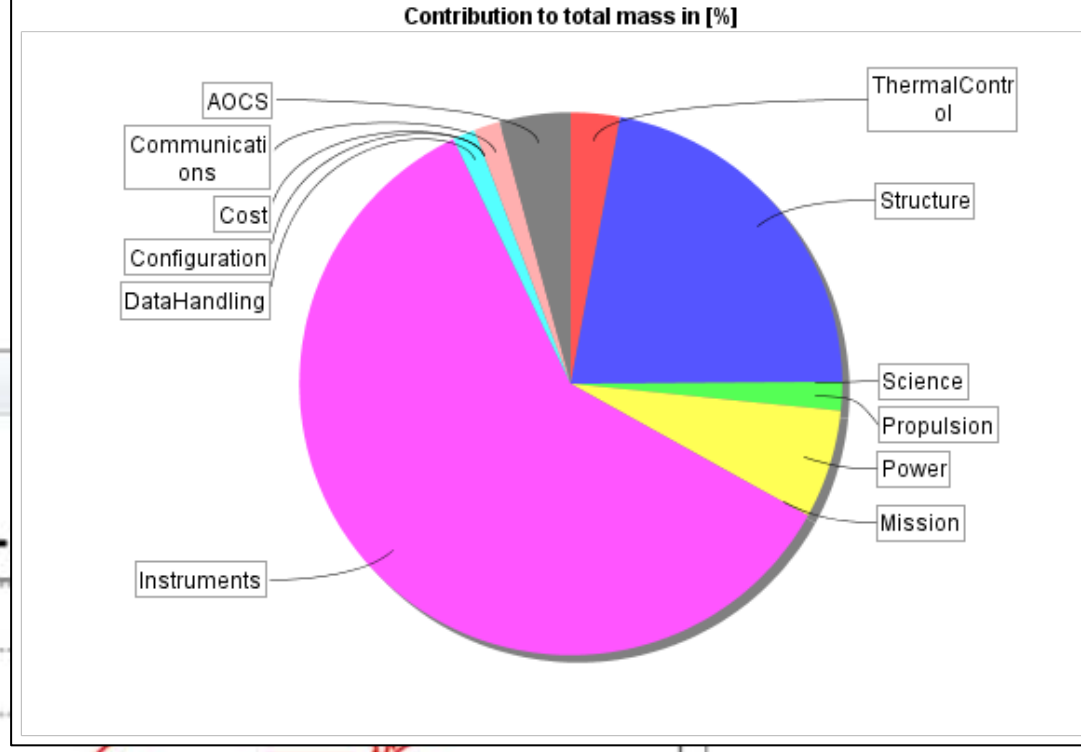
- Dependency analysis
- Identifying links and design drivers
- Enables informed decision making
- Exploiting the content of the data model

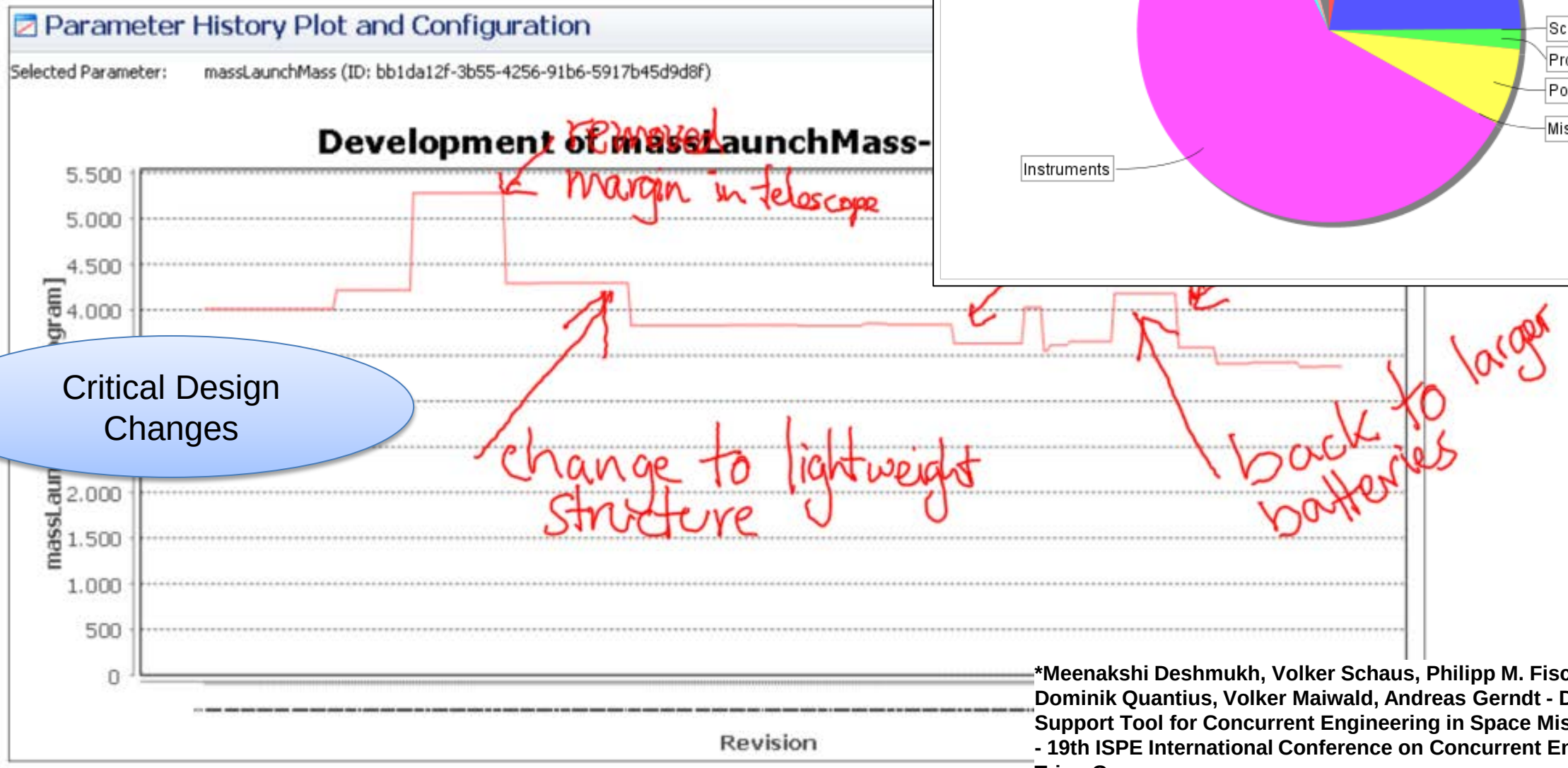




***Volker Schaus, Philipp M. Fischer, Dominik Quantius, Andreas Gerndt - Automated Sensitivity Analysis in Early Space Mission Design – SECESA Workshop 2012, Lisbon, Portugal**

Decision Support

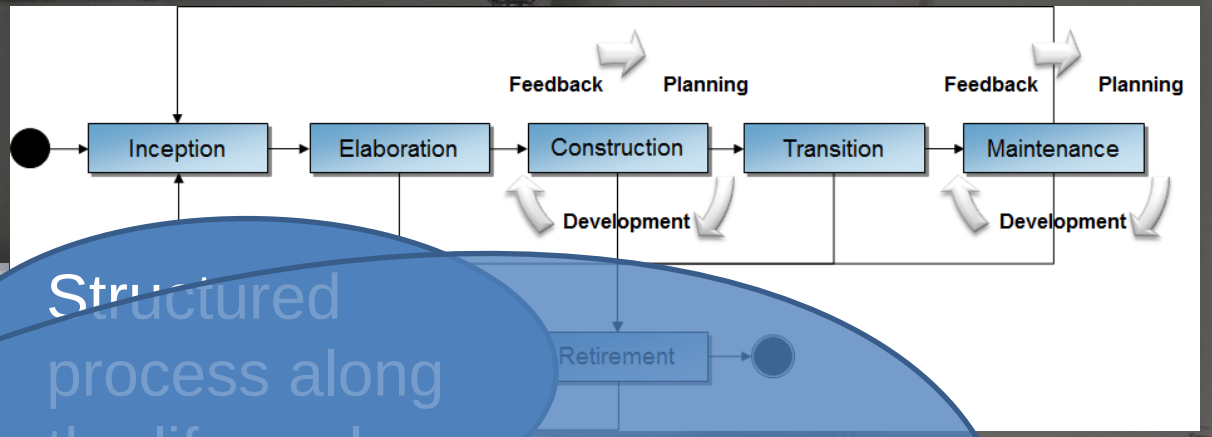


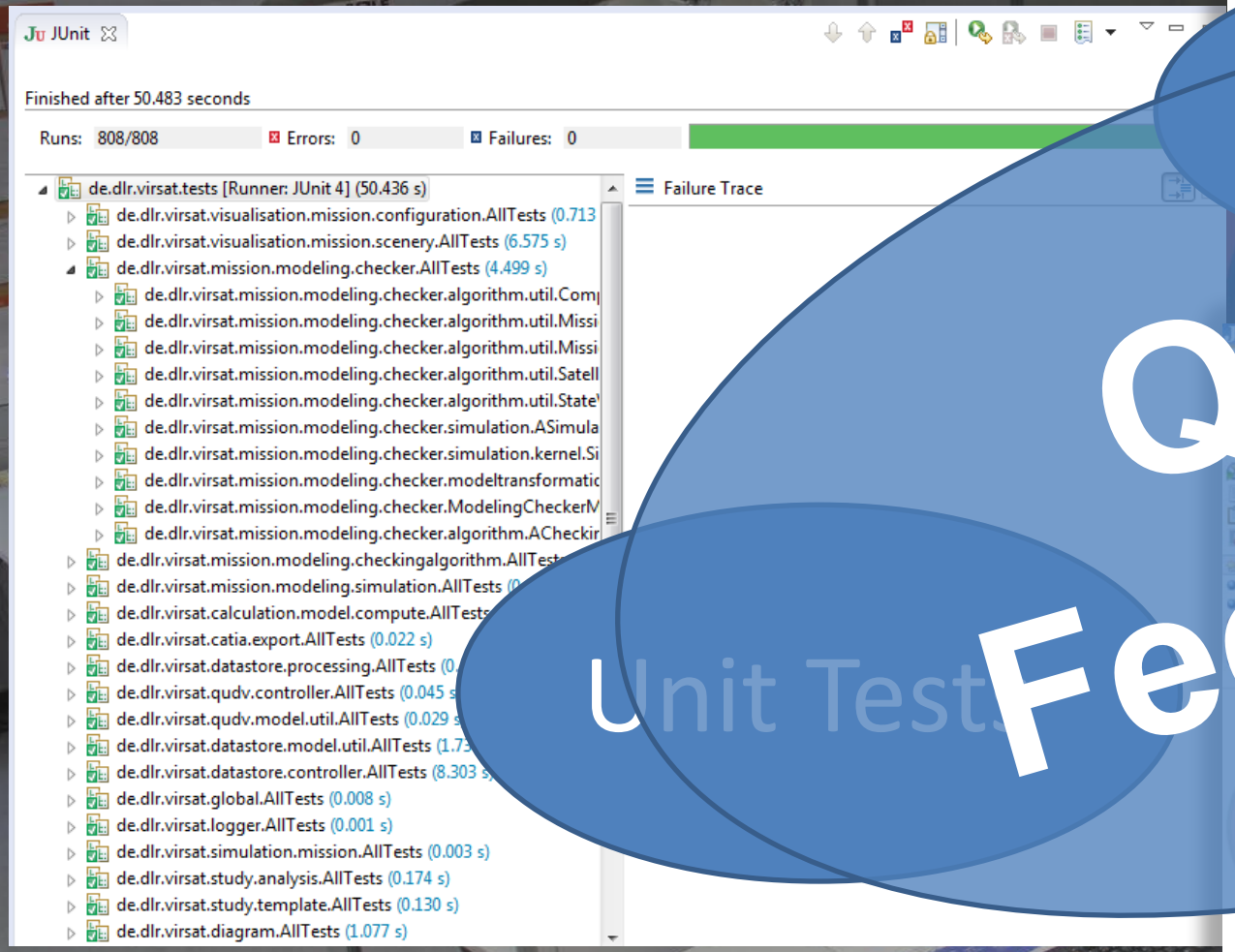


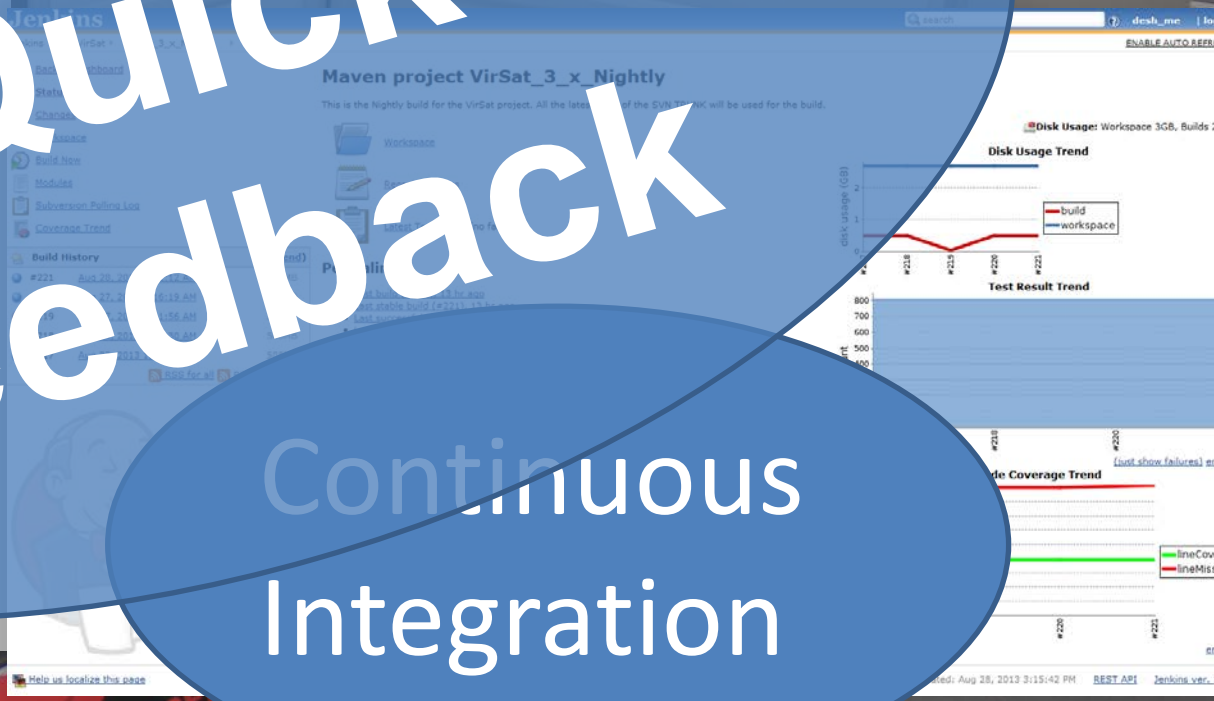
Critical Design Changes

***Meenakshi Deshmukh, Volker Schaus, Philipp M. Fischer, Dominik Quantius, Volker Maiwald, Andreas Gerndt - Decision Support Tool for Concurrent Engineering in Space Mission Design - 19th ISPE International Conference on Concurrent Engineering, Trier, Germany**

Software Engineering







Structured process along the life cycle

Quick Feedback

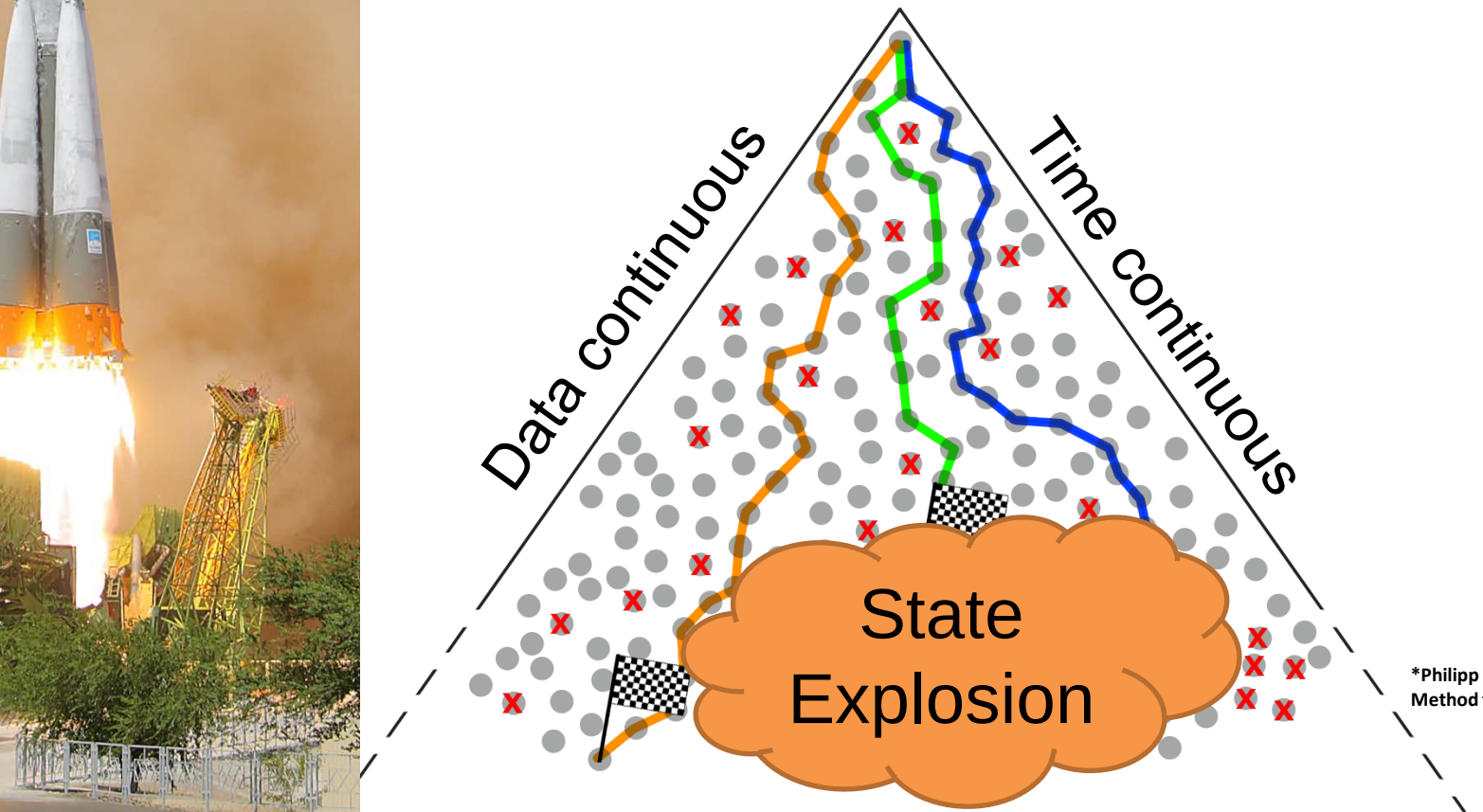
Unit Tests

Continuous Integration

Formal Verification in the Space Domain

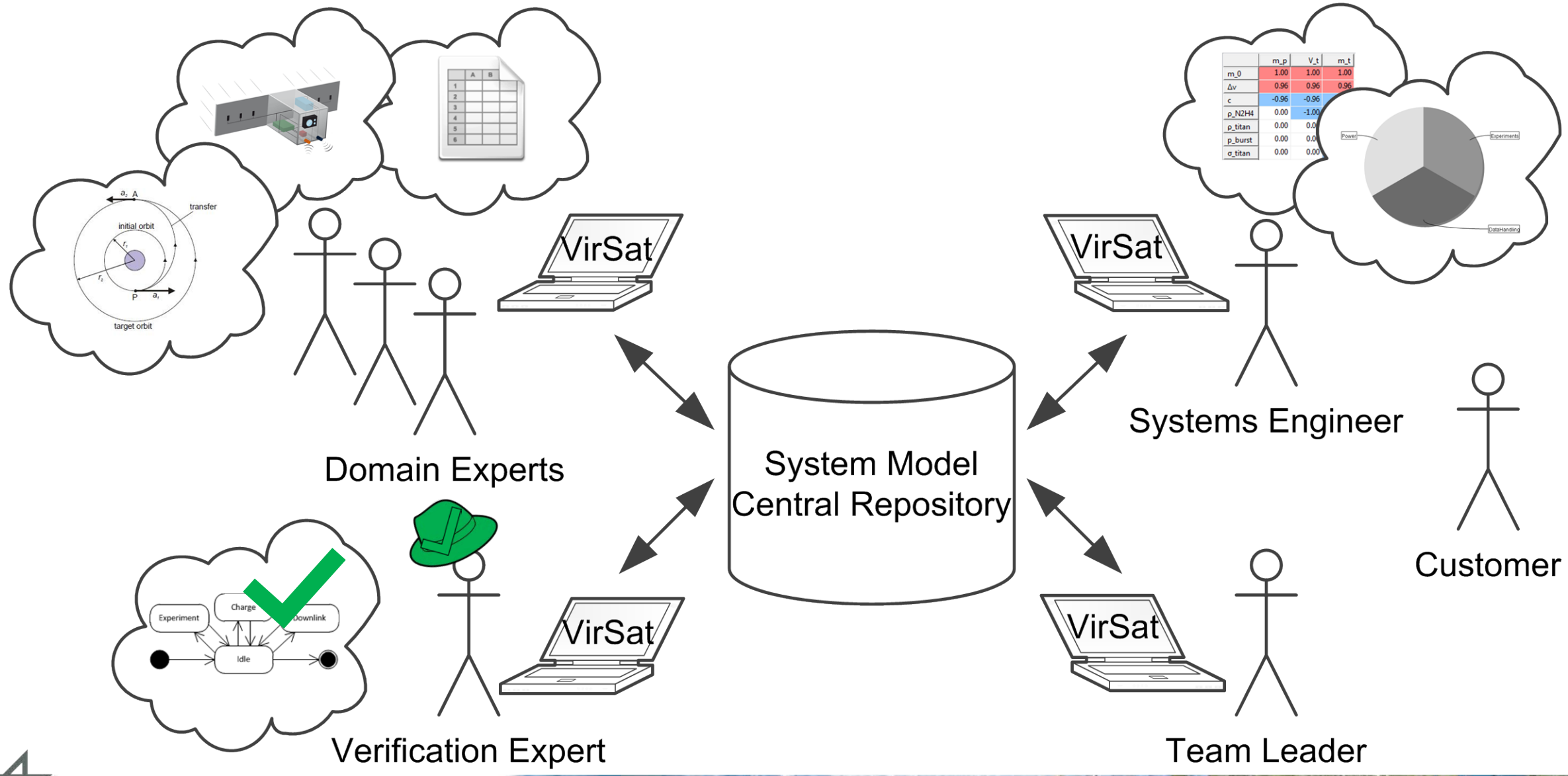

Image: DLR.de

State Machine → Informed Search Algorithm → Result

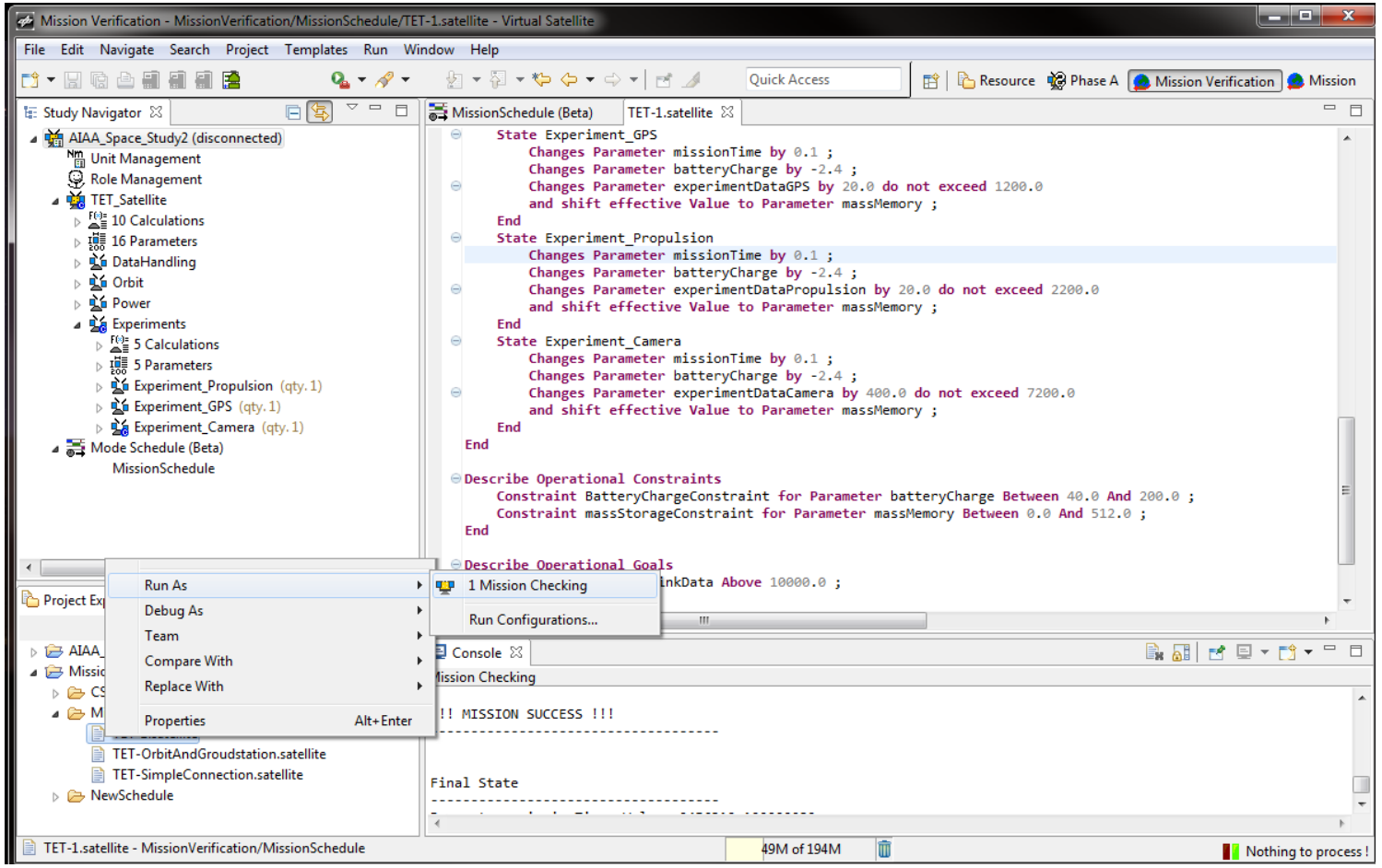


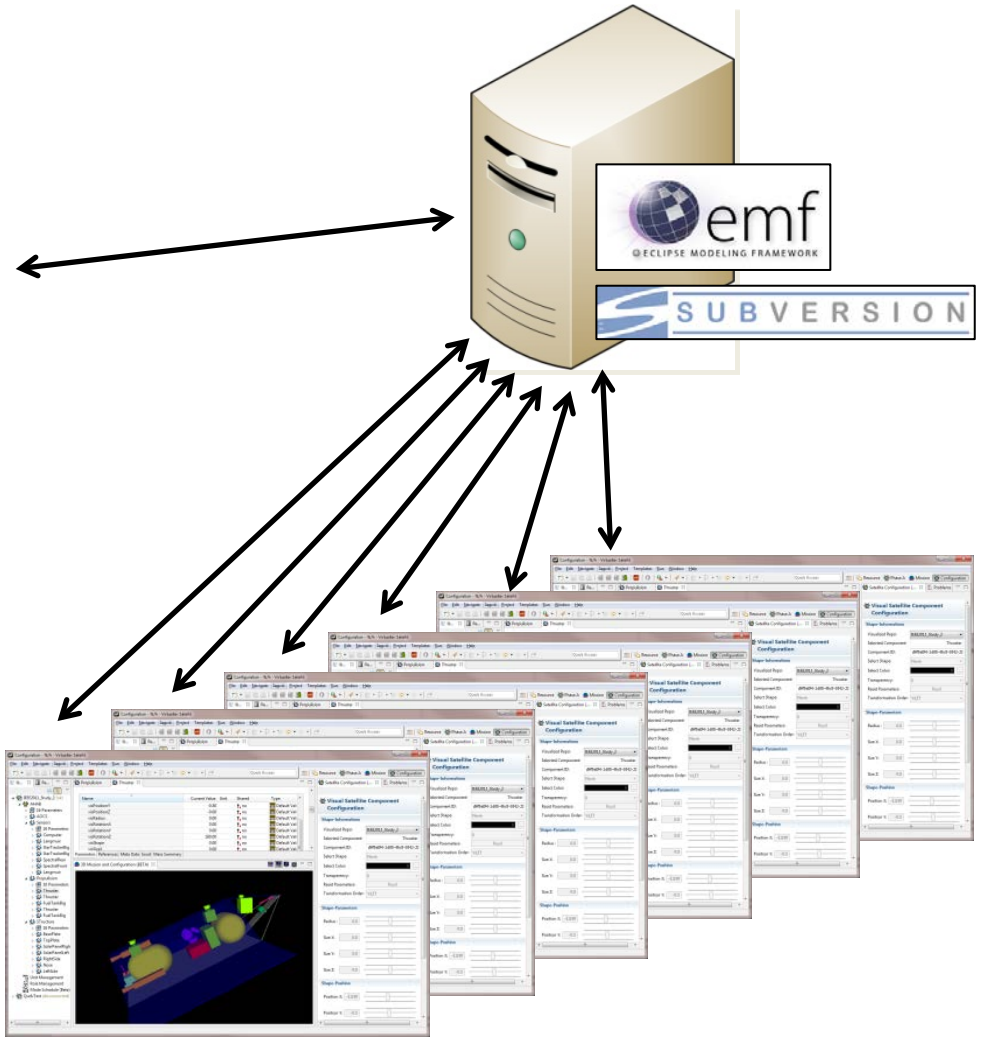
*Philipp M. Fischer, Daniel Lüdtke, Volker Schaus, Andreas Gerndt - A Formal Method for Early Spacecraft Design Verification – IEEE Aerospace 2013

Adding Verification to the CE core team

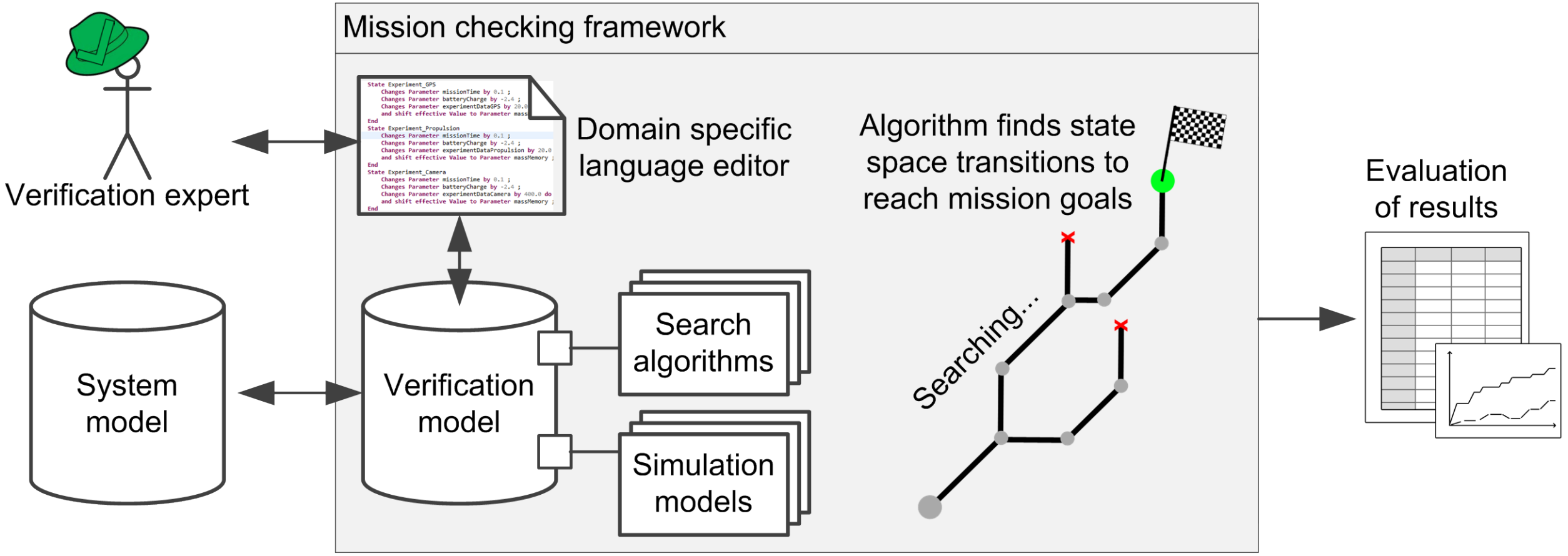


What is Virtual Satellite? – CE Software Tool





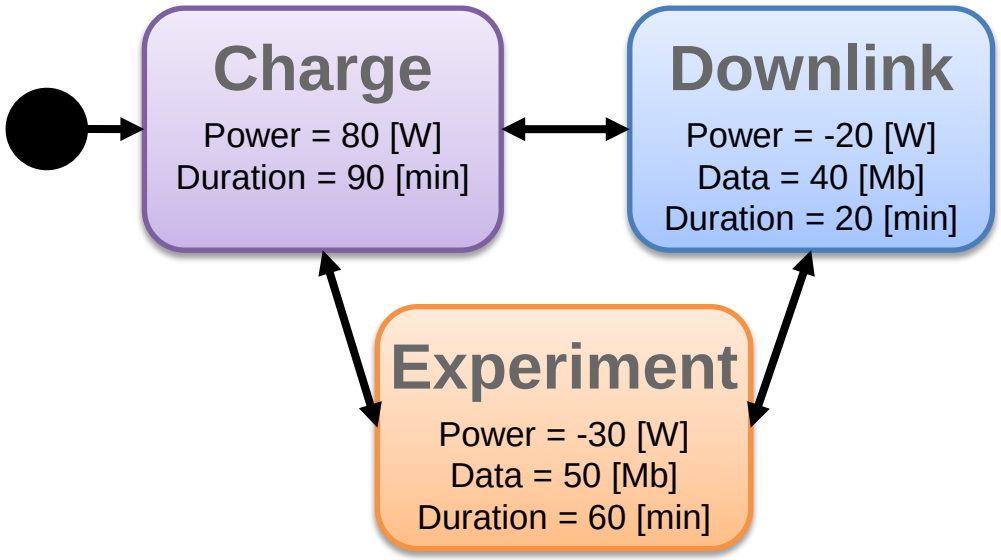
Work Process



***Volker Schaus, Michael Tiede, Philipp M. Fischer, Andreas Gerndt - A Continuous Verification Process in Concurrent Engineering – AIAA Space 2013, Sane Diego**

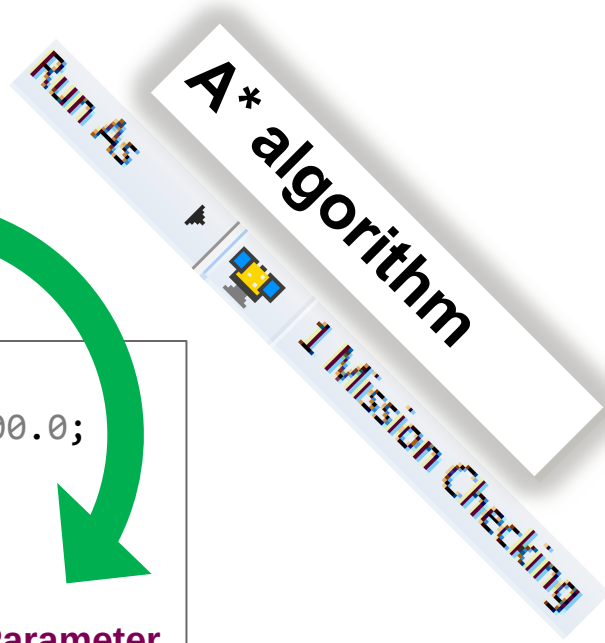
Defining the Verification Model – Running the Search

Describe State Machine → Define Goals and Constraints → Run Search



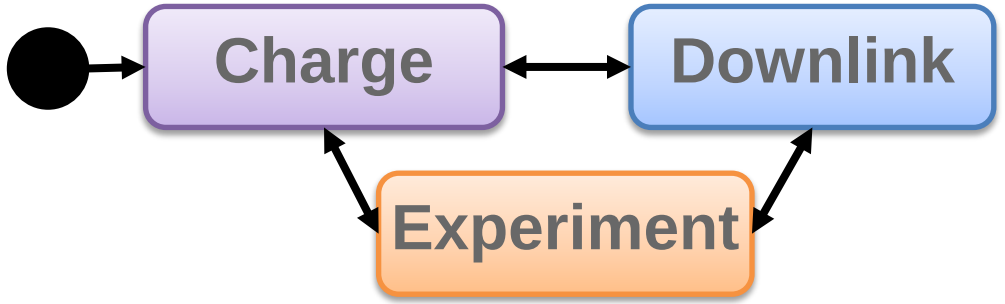
Req.: 10 GB of data in one year

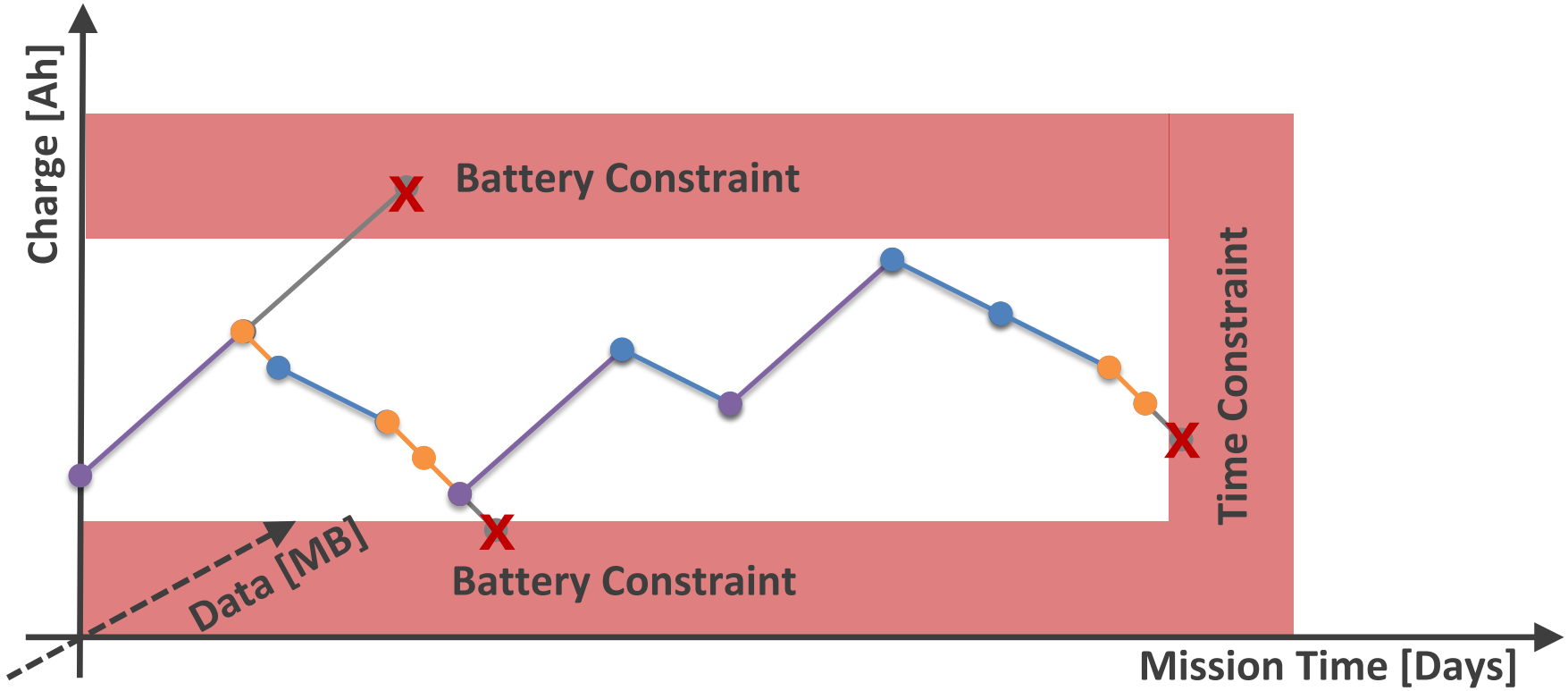
Con.: Max. battery capacity 240 Ah
Con.: Min. charge level 40Ah



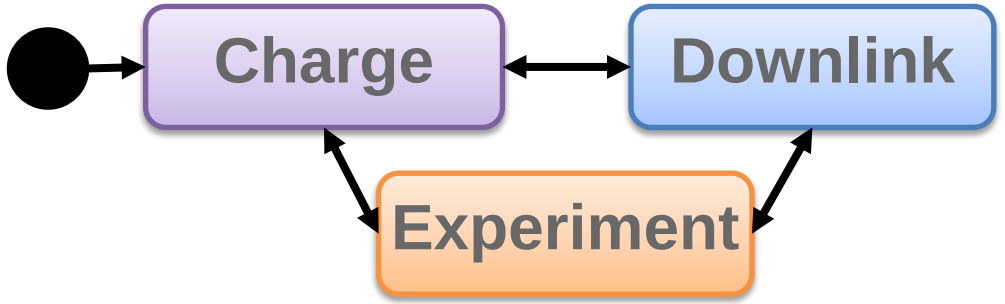

```
Describe Operational Goals
    Parameter TotalDownlinkData  Above 10000.0;
    Parameter MissionTime  Below 365.0;
End
Describe Operational Constraints
    Constraint BatteryChargeConstraint for Parameter
    batteryCharge Between 40.0 And 240.0 ;
End
```

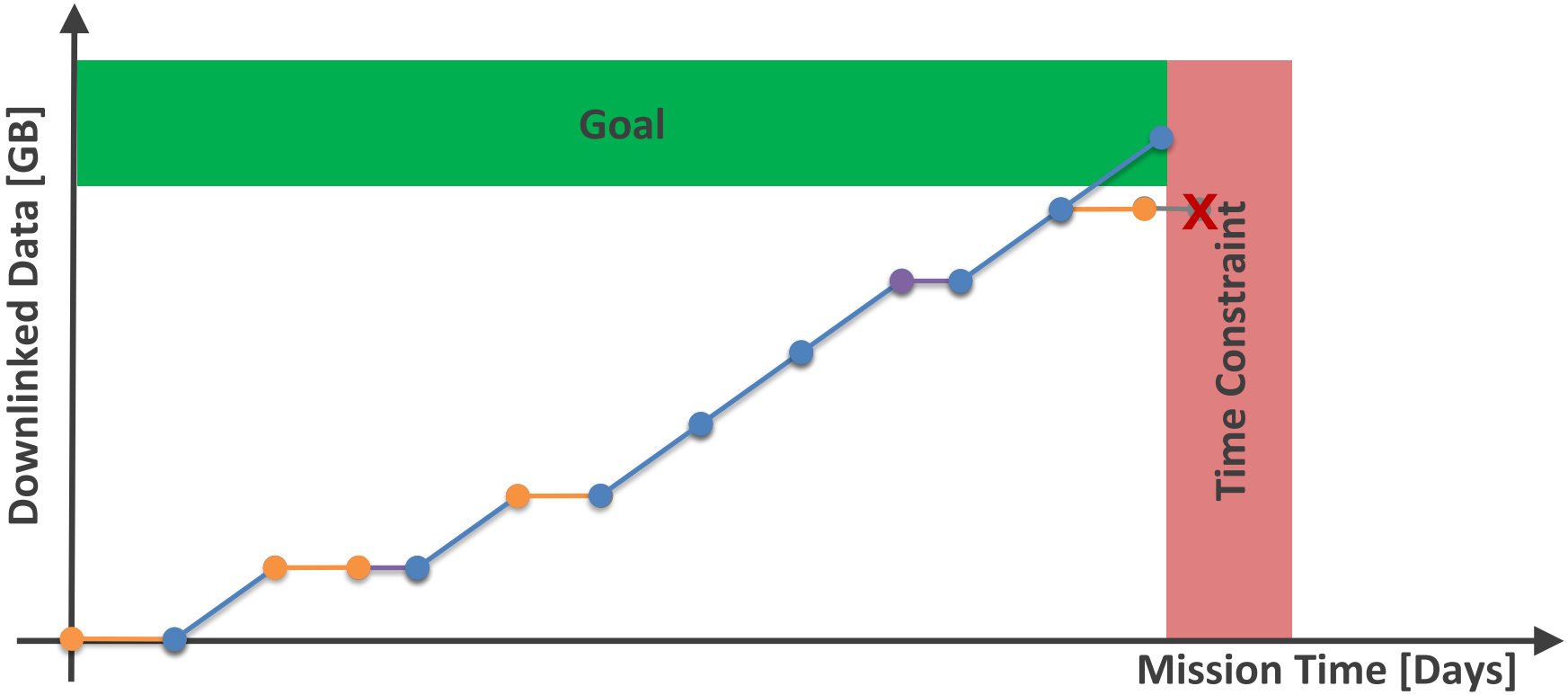
Result – Sequence of Mode Switches





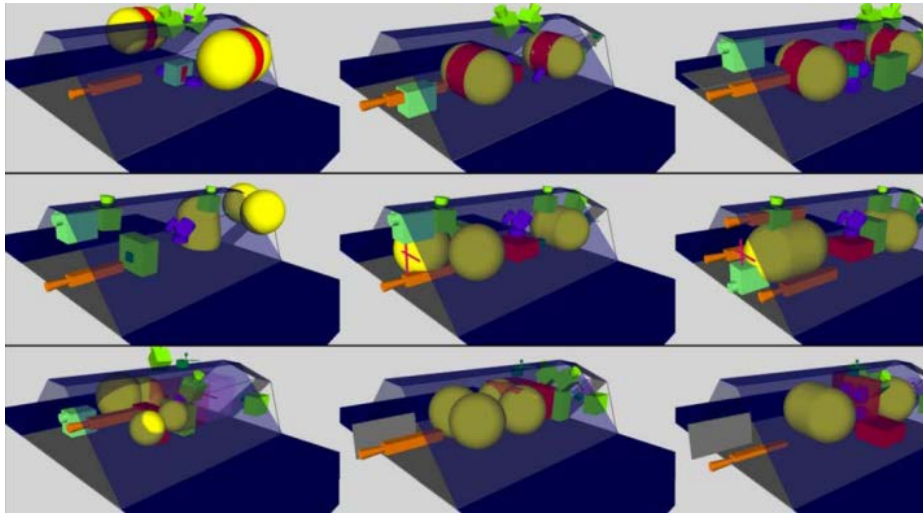
Result – Sequence of Mode Switches



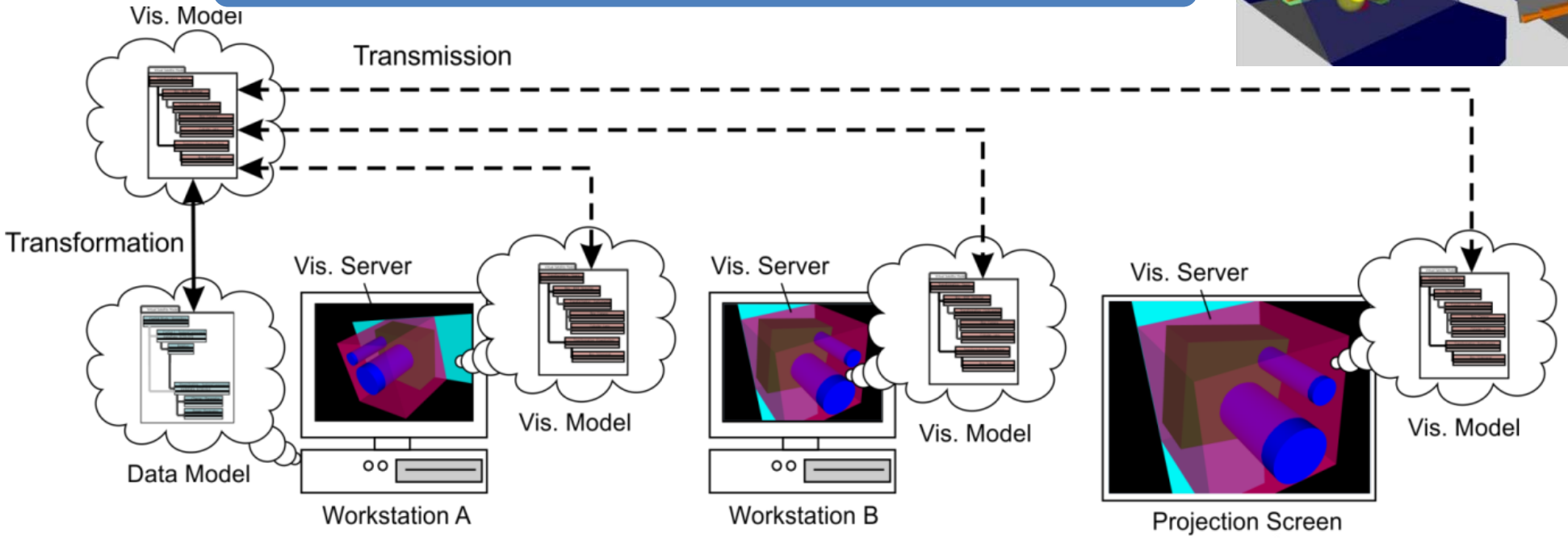


Generation of Project Related Artifacts

Collaborative Configuration supported by Interactive Visualization



- Integrated visualization model
- Connection to virtual reality environments

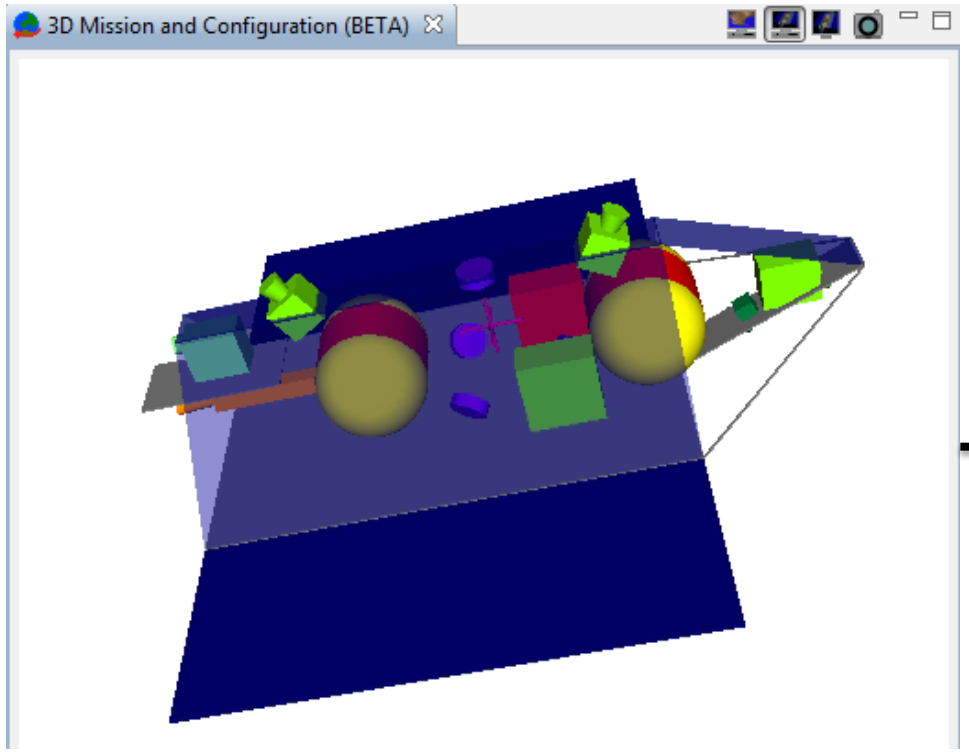


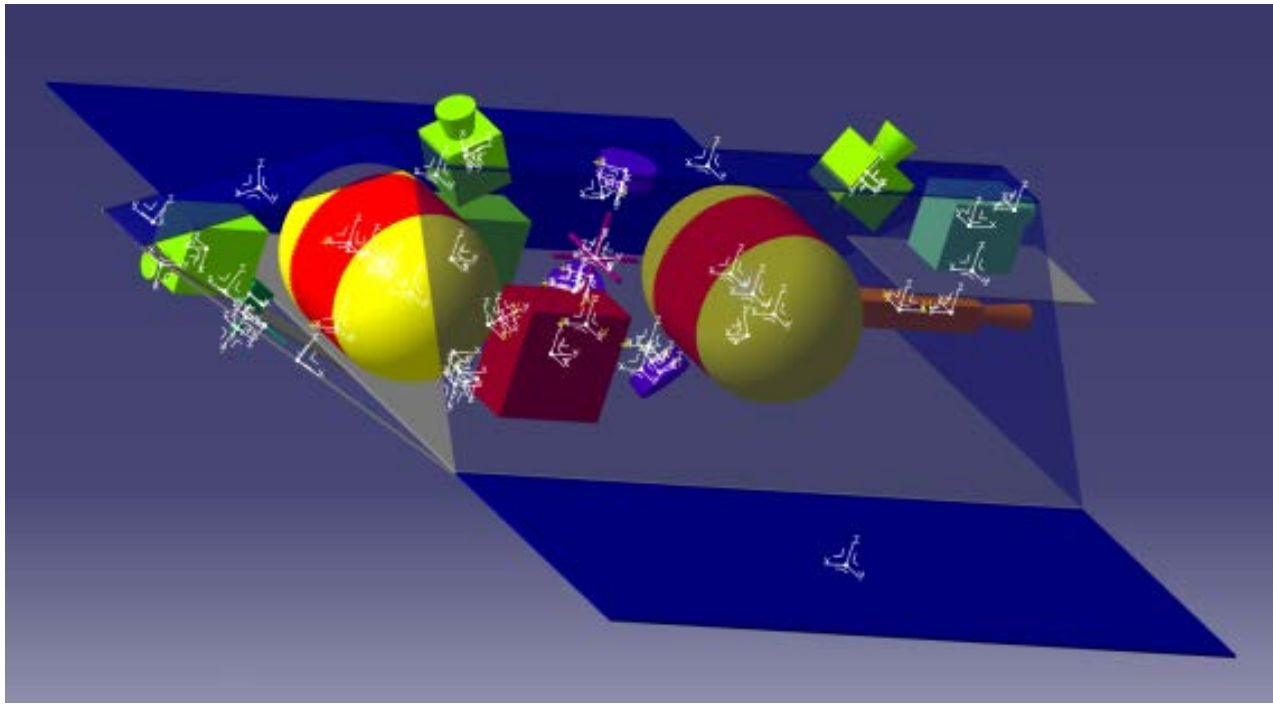
IEEE [Publication at IEEExplore]

CAD Interface: CATIA Export

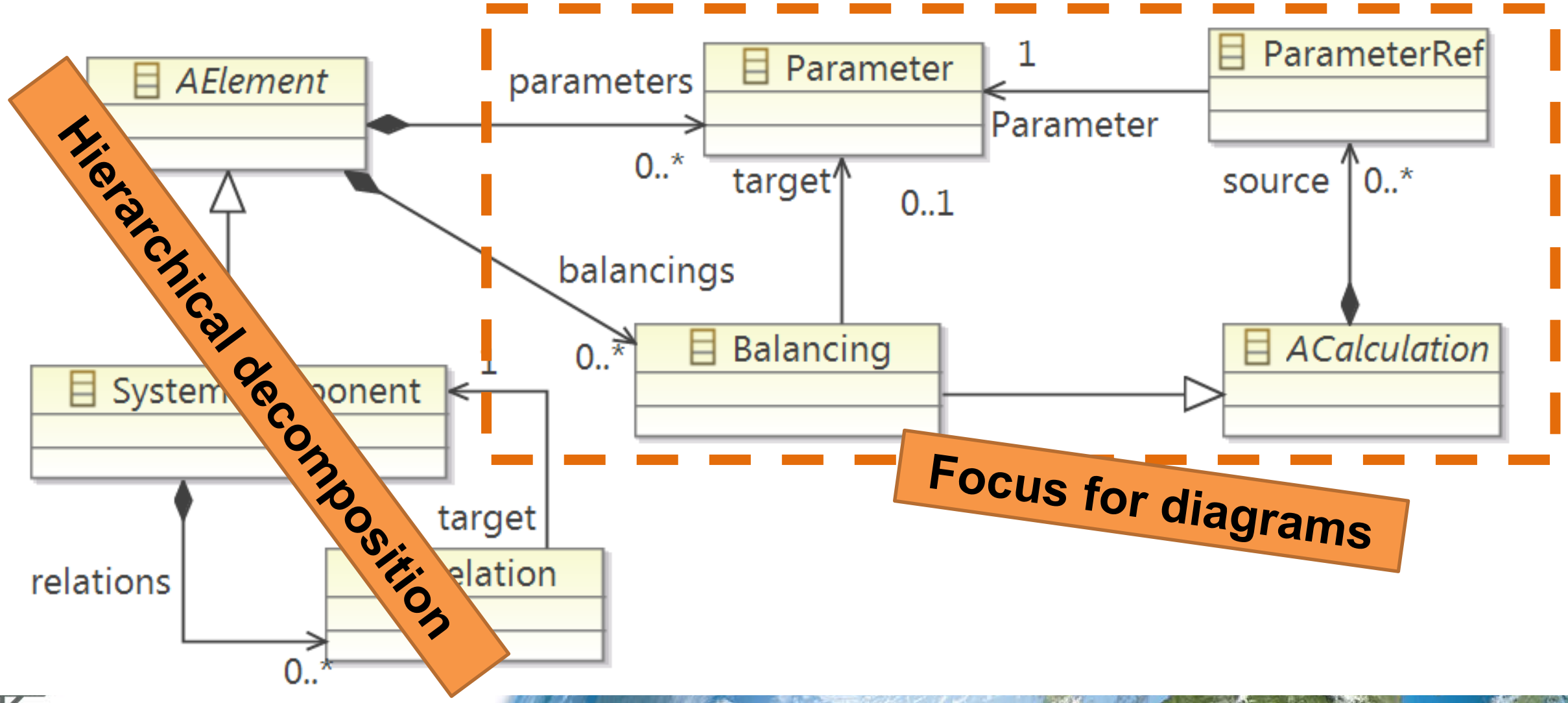
Fully automatic export to standard CAD tool

Saves time for configuration engineer





Motivation: Data Model and the References



Current State

- Diagram_Test_Study (ok)
  - Crazy_Mission
    - 13 Parameters
    - 8 Calculations
    - AOCS
    - COMMS
    - MISSION_ANALYSIS
      - 1 Parameter
        - Δv : 314.00 : m¹ s⁻¹
    - STRUCTURE
    - PROPULSION
      - 4 Calculations
      - 4 Parameters
    - INSTRUMENTS

ParameterR

Not visible!
Hard to trace!

Propulsion

Output Parameters

Parameters of this System Component

Name	Current Value	Unit	Shared	Type	Description
m_p	207.68	kg	no	Calculated Value	mass of the required propellant
Δv	165.00	m¹ s⁻¹	no	Calculated Value	equired change of velocity to fulfill the mi
V_t	0.21	m³	yes	Calculated Value	olume of the tank
c	2300.00	m¹ s⁻¹	no	Default Value	exhaust speed of the nozzle
m_0	3000.00	kg	no	Default Value	total mass of the system (launch mass)
ρ_N2H4	1008.00	kg m⁻³	no	Default Value	ensity of hydrazine
p_burst	5200000.00	Pa	yes	Default Value	urst pressure of the tank

Add Edit Remove

Calculations

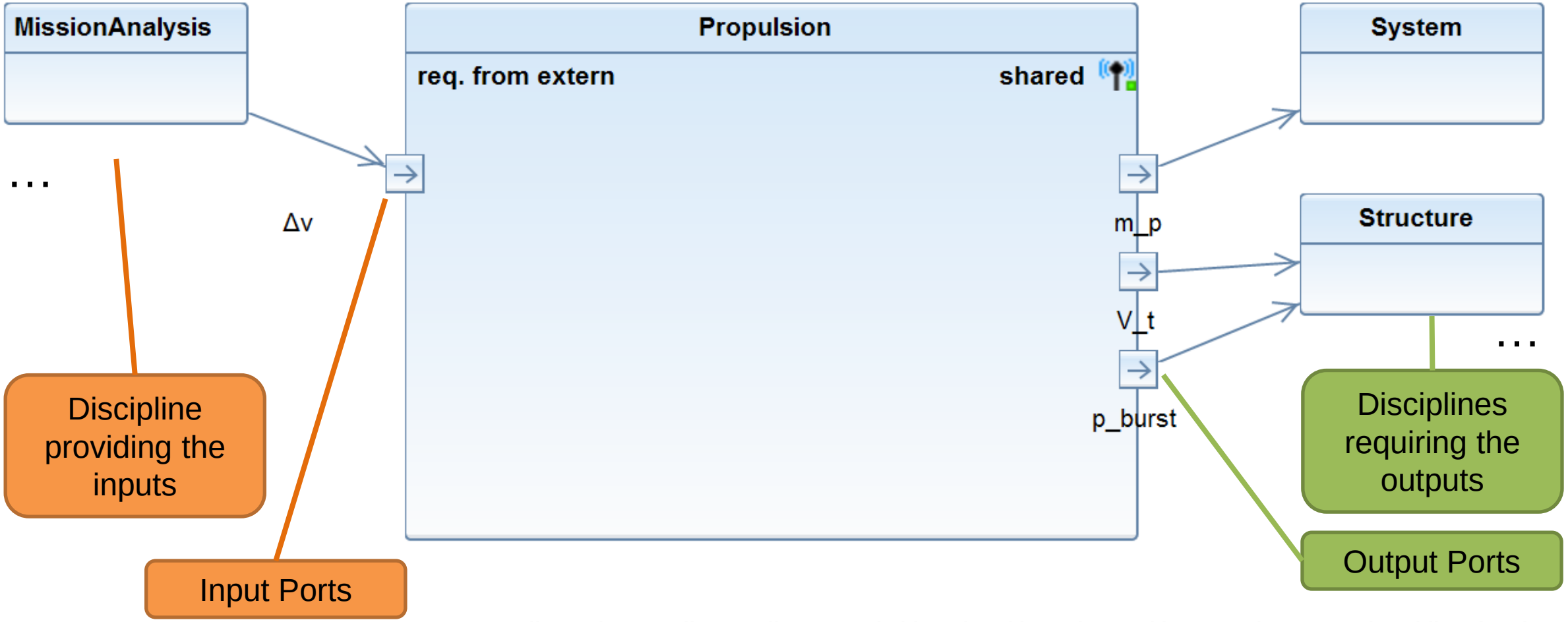
calculations for this System-Component

Calculation Type	System-Component	Parameter	Current Value	Unit	Description
Math - Assign	...	Δv	165.00	m¹ s⁻¹	N/A
	MissionAnalysis	Δv	165.00	m¹ s⁻¹	N/A
		V_t	0.21	m³	N/A
	pulsion	m_p	207.68	kg	mass of the required propellant
	pulsion	ρ_N2H4	1008.00	kg m⁻³	density of hydrazine
		m_p	207.68	kg	N/A
	ropulsion	m_0	3000.00	kg	total mass of the system (launch mass)
	Propulsion	Δv	165.00	m¹ s⁻¹	required change of velocity to fulfill the mi
	Propulsion	c	2300.00	m¹ s⁻¹	exhaust speed of the nozzle

a Data | Excel | Calculation | Visualization

DLR

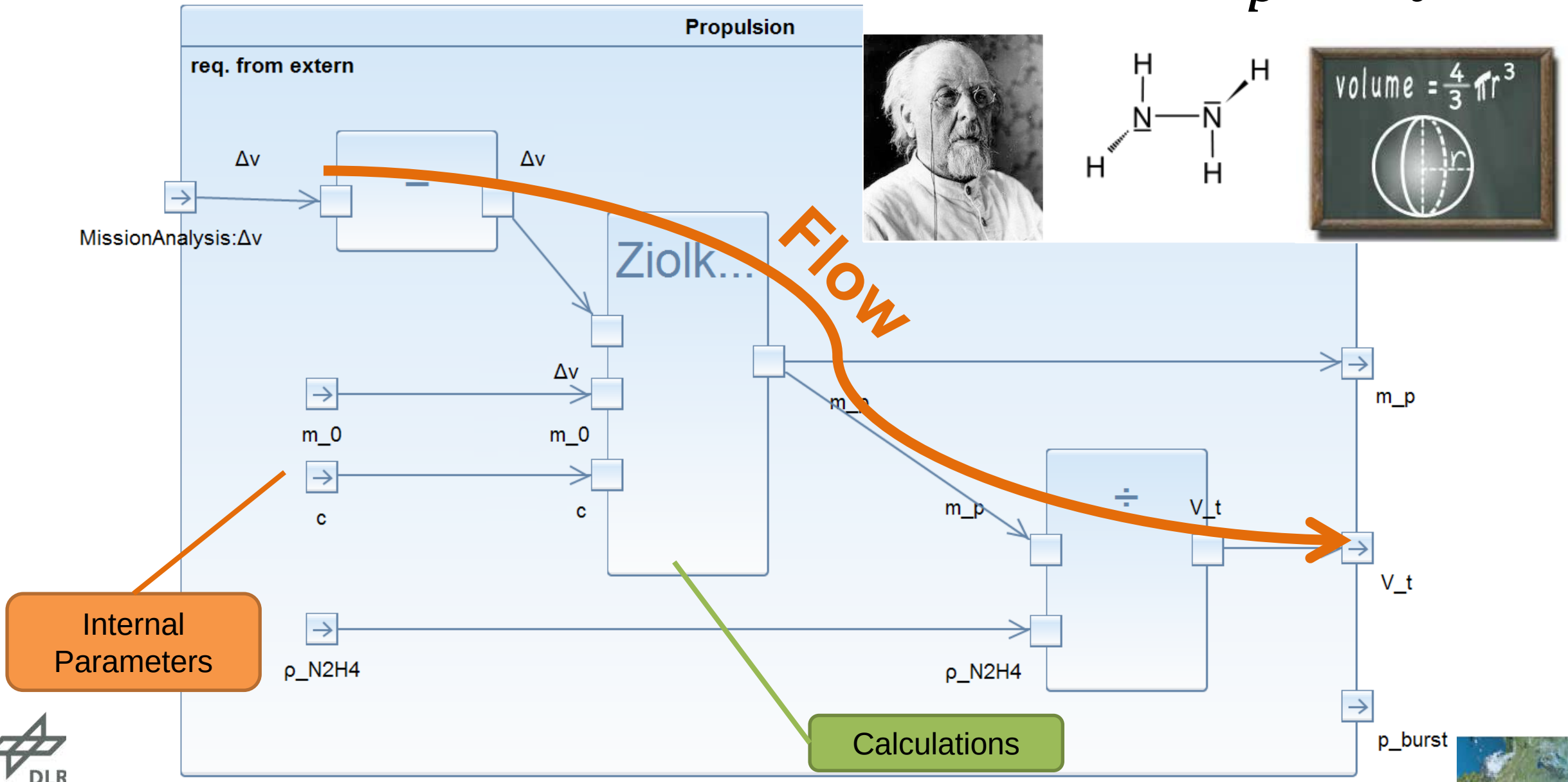
Interface Diagram



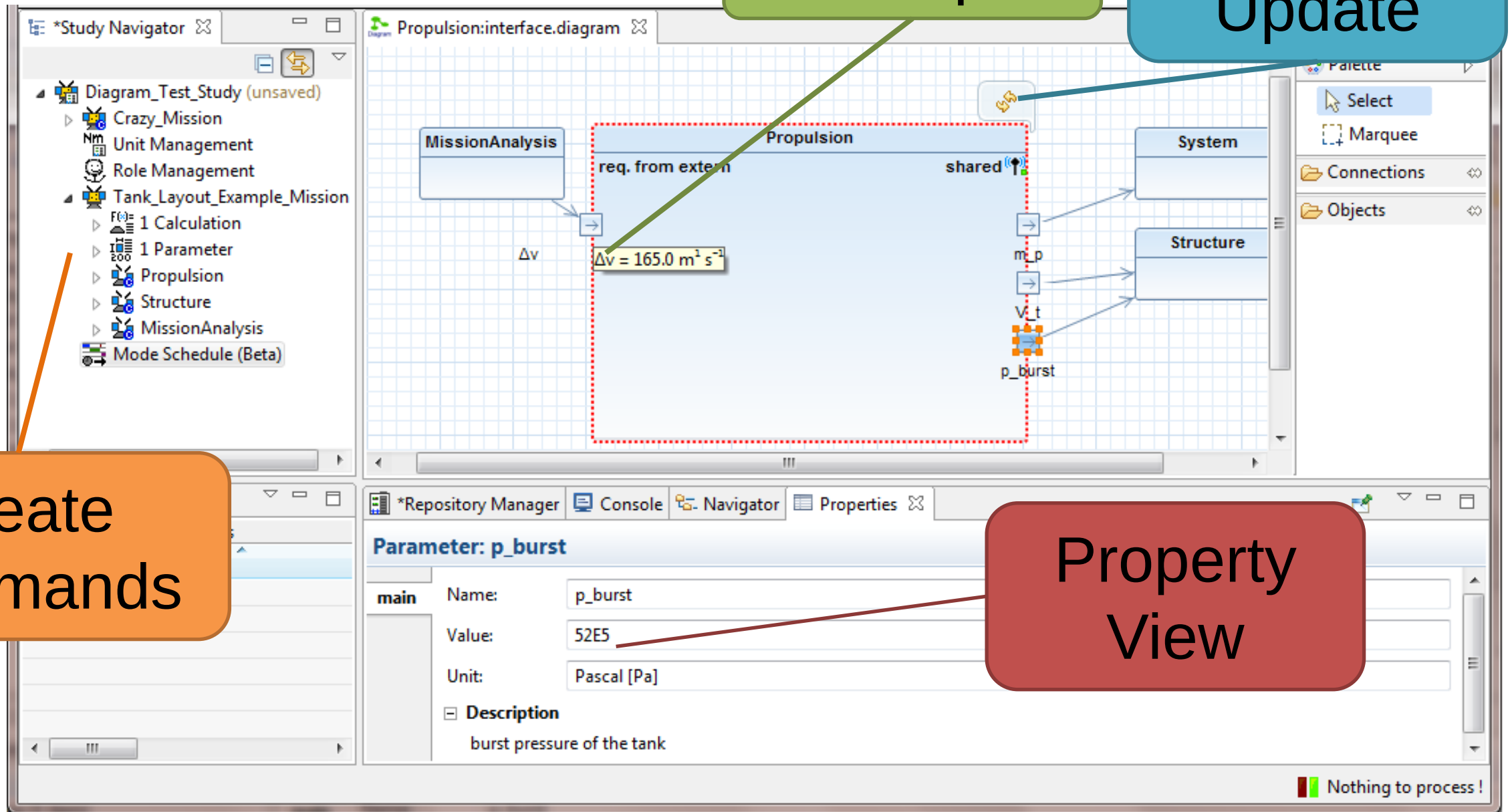
*Volker Schaus, Juliane Müller, Meenakshi Deshmukh, Andy Braukhane, Andreas Gerndt - Bidirectional Graphical Modelling Supporting Concurrent Spacecraft Design – SECESA Conference 2014, Stuttgart Germany

Internal Block Diagram

$$\Delta v \rightarrow m_p \rightarrow V_t$$



Integration in the Software



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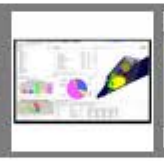
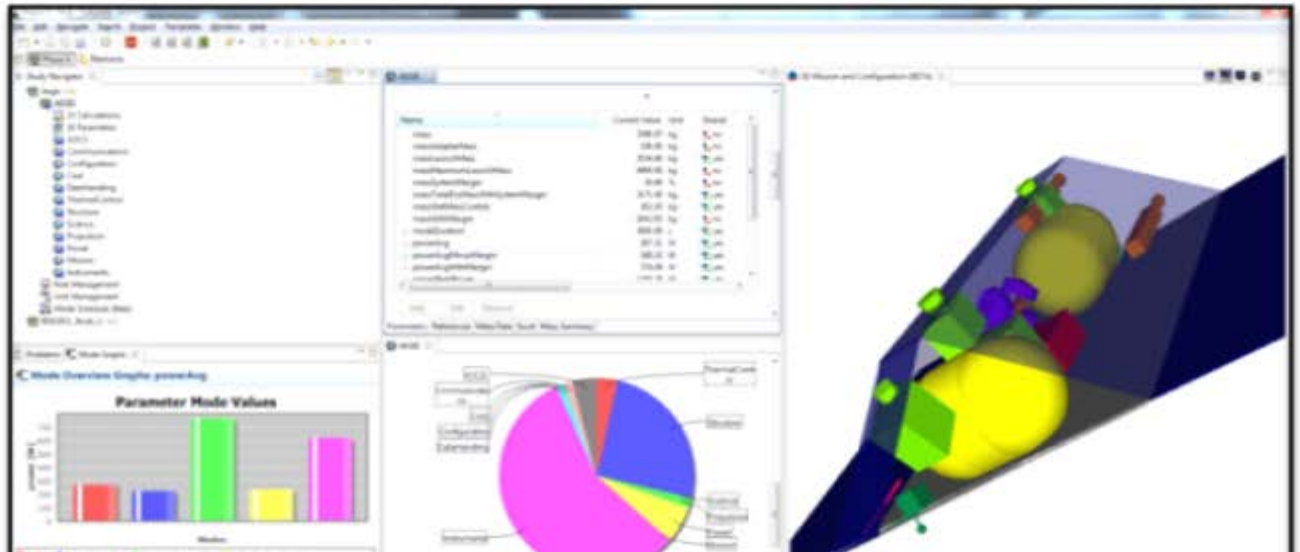
Simulation and Modeling

Model-based Systems Engineering Tool





License

Eclipse Public Lice

Programming Language

Java

Development Status

5 - Production/Stable

Operating System

64-bit MS Windows

Research Program

Institute

Simulation and Software Technology

Summary

Model-based Systems Engineering, Concurrent Engineering

- Space, Aircraft Design, …

Semantics

- QUDV example
- Early Verification

System Analysis

- Sensitivity
- Decision Support
- Dependency Visualization with Diagrams

Artifact Generation

- Geometric Model

Enabeling Technology

Questions ?

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